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An investigation of the effect of preparation on response execution and inhibition in the go/nogo task

Janette L. Smith
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**AN INVESTIGATION OF THE EFFECT OF
PREPARATION ON RESPONSE EXECUTION
AND INHIBITION IN THE GO/NOGO TASK**

A thesis submitted in fulfilment of the requirements for
the award of the degree

DOCTOR OF PHILOSOPHY

from the

UNIVERSITY OF WOLLONGONG

by

JANETTE L. SMITH, BPsyc (Hons)

DEPARTMENT OF PSYCHOLOGY

2005

I, Janette L. Smith, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Department of Psychology, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Janette Smith

20 October 2005

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Abstract

In five studies, this thesis examined inhibitory processing in the Go/NoGo task, during which participants were instructed to either execute or withhold a prepared response. These studies extended previous Go/NoGo research by investigating the relationship between prior response preparation and subsequent inhibitory processing, with the aim of clarifying the relationship between the N2 and P3 ERP components and inhibitory processing. This was achieved by (1) the use of a fixed foreperiod prior to the Go/NoGo stimulus, (2) the concurrent examination of other components related to stimulus perception (e.g., N1, P2, early CNV) and action (e.g., the late slow wave), (3) the use of both overt and covert responses, and (4) the use of informative cues to elicit differential preparation for a Go or NoGo stimulus. The main results were that a NoGo N2 effect can be robustly observed using auditory stimuli, but that the N2 does not appear to reflect motor or cognitive/pre-motor inhibition, or the detection of conflict between responses. The NoGo P3, however, behaved in a fashion consistent with an inhibitory interpretation, being increased following higher levels of preparation for a response, absent when no inhibition was required to NoGo stimuli, and increased over the brain region specifically involved in motor commands. The results cast doubt on the current inhibitory and conflict interpretations of the N2, and suggest rather that the P3 may represent an inhibitory process.

Overview

This thesis aimed to extend knowledge regarding the functional significance of the N2 and P3 event-related potential (ERP) components in the Go/NoGo inhibition task. This was achieved via the elicitation of response preparation prior to the imperative (i.e., Go or NoGo) stimulus in a fixed foreperiod (S1-S2) paradigm, based on the logic that highly prepared responses are difficult to inhibit. An examination of N2 and P3 NoGo effects following varying levels of response preparation was used to test current theories of these components' functional significance (i.e., that the N2, but not the P3, reflects the inhibition of a response, or the detection of response conflict). Study 1 considered the inhibitory processes following high and low levels of response preparation within-subjects, in a paradigm where inhibition was rarely required. Study 2 provided a between-subjects assessment of the inhibitory processes in a group of Fast and Slow responders to Go stimuli. In both Studies 1 and 2, the relationship of the N2 and P3 to the late contingent negative variation (CNV) and other components was determined using regression analyses. In Study 3, the effect of trial sequence on the responses to both Go and NoGo stimuli was examined, and Study 4 considered the effect of overt vs. covert responding on typical Go/NoGo effects. The final study introduced the use of informative cues to differentially predict bimanual responses, and allowed the examination of other theories of the N2 (that is, the conflict model).

The first three chapters of the thesis provide a brief introduction to the common interpretations of several ERP components (Chapter 1), and comprehensive reviews of the literature on preparation and anticipation (Chapter 2), and inhibition (Chapter 3). The final section of Chapter 3 brings together the literature from these two areas, which have remained largely separate until now.

Study 1 (Chapter 4) investigated inhibitory processing in 44 adult participants who completed a warned Go/NoGo task with 70% Go stimuli. A within-subject median split of reaction time on Go trials allowed topographic analysis (over nine scalp sites) of ERP components associated with Fast and Slow Go responses, as well as with NoGo stimuli. The components measured in all studies were the S1-N1, S1-

P2, early CNV and late CNV (occurring in the S1-S2 interval), and also the S2-N1, S2-N2, S2-P3 and late slow wave (LSW) following the presentation of Go/NoGo stimuli. In addition to the typical analyses comparing N2 and P3 on Go and NoGo trials, a median split of NoGo trials following high- and low-amplitude late CNV allowed a direct investigation of inhibitory processes in relation to response preparation. Furthermore, regression analyses enabled examination of the relationship of components in the foreperiod to post-S2 events, including reaction time and the N2 and P3 inhibitory effects. The usual NoGo > Go effect was observed for N2 amplitude, as well as a frontocentral increase in NoGo P3 amplitude. NoGo P3 was larger following high levels of preparation, an effect not present for the NoGo N2. Further, the NoGo P3 effect, but not the NoGo N2 effect, was significantly related to the late CNV in regression analyses. These results suggest that the NoGo P3, rather than the NoGo N2, may reflect inhibition.

Study 2 (Chapter 5) aimed to replicate and extend the findings of the first study in a between-subjects analysis of Fast and Slow responders to Go stimuli. The data from 32 participants in a warned Go/NoGo task with equiprobable Go/NoGo stimuli were analysed, with the hypothesis that inhibition would be more difficult for the group of Fast responders. Despite a higher level of response preparation (larger late CNV) in the Fast responders, they did not display a larger N2 NoGo effect than the Slow responders. In contrast, the P3 NoGo effect was greater in the Fast responders. Similar to the first study, regression analyses showed that the NoGo N2 was unrelated to prior preparation, while the NoGo P3 was significantly related to the late CNV. The results of Study 2 confirm the conclusion of Study 1, that the NoGo N2 is not related to inhibition, while the NoGo P3 does display characteristics indicative of an inhibitory process.

In Study 3 (Chapter 6), an analysis of the effect of stimulus sequence on responses to Go and NoGo stimuli was undertaken. It was hypothesised that, as Go responses became faster with repetitions of Go stimuli, inhibition of the response to the NoGo stimulus would be more difficult. To test this, 26 participants completed a warned Go/NoGo task (75% Go stimuli) with the number of Go stimuli that preceded each NoGo trial varying systematically. Participants' responses to a post-experimental questionnaire indicated that inhibition was most difficult

following a long run of repetitive Go stimuli. The N2 NoGo effect was greatest when expectancy for a Go stimulus was high (directly after another NoGo trial), but the effect did not change over short to long runs of preceding Go stimuli. In contrast, the NoGo P3 did increase with the number of immediately preceding Go responses. If participants' reports are correct, then the NoGo P3 may be more strongly related to the inhibitory process than the NoGo N2.

Because many researchers have discussed the notion of movement-related potential overlap causing the observed P3 NoGo effect, Study 4 (Chapter 7) aimed to examine the effect of overt vs. covert responding on inhibitory processing. Twenty adult participants completed two versions of a warned-Go/NoGo task, with low probability Go and NoGo stimuli (20% each) as well as high probability Go trials (60%). Two versions were completed – in one condition, participants were required to count the number of Go stimuli, while in another condition they were to make a fast button press in response to Go stimuli. The N2 NoGo effect did not differ between the Count and Press tasks, but the P3 NoGo effect was much larger during the overt response (i.e., Press) task. Additionally, subtraction of the ERP waveform for Count NoGo from Press NoGo trials (forming a difference wave indicative of processes related specifically to motor inhibition) revealed a positive wave between 200 to 400 ms, occurring maximally over the central region, contralateral to the responding hand. This difference wave became significant in the range 210-260 ms at most sites, which may indicate that this activity reflects a motoric inhibition process.

The final study (Chapter 8) introduced the use of informative cues to prime bimanual responses, with the aim of directly manipulating the amount of inhibition required when a NoGo target was presented. In addition, the use of invalid priming (where the target demands the opposite response to that planned) allowed examination of the conflict interpretation of N2. Twenty-six adult participants completed the task, and showed significant reaction time benefits with valid cueing, and costs with invalid cueing. Analyses of the late CNV showed that participants used the information provided by the cue to prepare their responses. The NoGo N2, however, did not increase according to these prior levels of preparation, and was in fact largest when participants had not prepared a response at all, which may

be taken as strong evidence against its inhibitory interpretation. Additionally, the N2 was smaller on invalidly-cued trials, in contrast to predictions from a conflict account of the N2. However, the NoGo P3 increased with prior levels of preparation, and the invalidly-cued P3 was larger than when validly cued. The study provides further evidence that the NoGo P3, not the NoGo N2, represents an inhibitory process.

Chapter 9 provides a summary and discussion of the results of this thesis in relation to current theories of response preparation, execution and inhibition. The relationship of the late CNV to reaction time across studies is examined, and the LSW is discussed as a response-related process. Further research is suggested on the motoric inhibition process identified in Study 4, particularly in relation to the stop-signal task and populations known to suffer behavioural disinhibition. It is concluded that the N2 represents neither inhibitory nor conflict processing, and that the P3 instead represents the inhibitory process.

Abbreviations used in the text

A-D	Analog to Digital
CNV	Contingent Negative Variation
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electrooculogram
ERN	Error-Related Negativity
ERP	Event-Related Potential
fMRI	Functional Magnetic Resonance Imaging
LRP	Lateralised Readiness Potential
LSW	Late Slow Wave
MMN	Mismatch Negativity
PCA	Principal Components Analysis
PN	Processing Negativity
RP	Readiness Potential
RSI	Response to Stimulus Interval
RT	Reaction Time
S1	Stimulus 1
S2	Stimulus 2
SOA	Stimulus Onset Asynchrony
SPL	Sound Pressure Level
SPM	Standard Progressive Matrices
SPN	Stimulus-Preceding Negativity
S-R	Stimulus-to-Response
SS	Standardised Score
SSRT	Stop-Signal Reaction Time
SW	Slow wave

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